US009462749B1

(12) **United States Patent**
Jens et al.

(10) **Patent No.: US 9,462,749 B1**
(45) **Date of Patent: Oct. 11, 2016**

(54) **SELECTIVELY HARVESTING FRUITS**

(71) Applicant: **Harvest Moon Automation Inc.**, Winchester, MA (US)

(72) Inventors: **Stephen Jens**, Winchester, MA (US); **Janice Huxley Jens**, Winchester, MA (US); **Edward Dickinson**, Leicester, MA (US)

(73) Assignee: **Harvest Moon Automation Inc.**, Winchester, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/696,037**

(22) Filed: **Apr. 24, 2015**

(51) **Int. Cl.**

G06K 9/00	(2006.01)
A01D 46/30	(2006.01)
G06T 7/00	(2006.01)
G06T 7/40	(2006.01)
G06K 9/46	(2006.01)

(52) **U.S. Cl.**
CPC ***A01D 46/30*** (2013.01); ***G06K 9/00536*** (2013.01); ***G06K 9/4652*** (2013.01); ***G06T 7/0004*** (2013.01); ***G06T 7/408*** (2013.01); *G06T 2207/30128* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

117,705	A	8/1871	Warren et al.	
218,795	A	8/1879	Thompson	
811,978	A	2/1906	Weigen	
2,544,023	A	3/1951	Johnson	
2,583,571	A	1/1952	Howe	
2,825,273	A	3/1958	Faucheux	
4,519,193	A *	5/1985	Yoshida	A01D 46/24 348/89

(Continued)

FOREIGN PATENT DOCUMENTS

EP	267860	A3	4/1990
EP	1002460	B1	4/2003

(Continued)

OTHER PUBLICATIONS

Authorized Officer E. Eskina, International Search and Written Opinion for International Application No. PCT/US2016/018859, dated May 12, 2016, 8 pages.

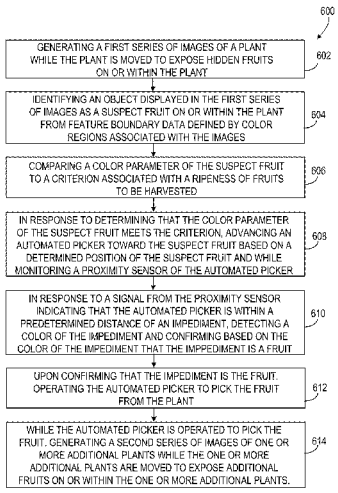
(Continued)

Primary Examiner — Shervin Nakhjavan
(74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

(57) **ABSTRACT**

A method of selectively harvesting fruits includes generating a first series of images of a plant while the plant is moved to expose hidden fruits, identifying an object displayed in the first series of images as a suspect fruit from feature boundary data defined by color regions, comparing a color parameter of the suspect fruit to a criterion associated with a ripeness, advancing an automated picker toward the suspect fruit based on a determined position of the suspect fruit and while monitoring a proximity sensor of the automated picker, detecting a color of the impediment and confirming that the impediment is a fruit, operating the automated picker to pick the fruit from the plant, and while the automated picker is operated to pick the fruit, generating a second series of images of one or more additional plants while the one or more additional plants are moved to expose additional fruits.

20 Claims, 6 Drawing Sheets
(2 of 6 Drawing Sheet(s) Filed in Color)



(56) **References Cited**

U.S. PATENT DOCUMENTS

4,532,757	A	8/1985	Tutle	
4,843,561	A	6/1989	Larson	
4,873,644	A *	10/1989	Fujii	A01D 46/24 56/10.2 R
4,975,016	A	12/1990	Pellenc et al.	
5,054,232	A	10/1991	Rhode	
5,544,474	A	8/1996	Finkelstein	
6,919,959	B2	7/2005	Masten	
7,215,420	B2	5/2007	Gellerman et al.	
7,725,233	B2	5/2010	Hendrickson et al.	
7,765,780	B2 *	8/2010	Koselka	A01D 46/30 56/10.2 A
8,272,200	B1	9/2012	Ottaway	
8,381,501	B2	2/2013	Koselka et al.	
8,452,501	B1	5/2013	Lange et al.	
8,642,910	B2	2/2014	Pellenc et al.	
8,841,570	B2	9/2014	Vasilescu	
8,855,412	B2	10/2014	Quan et al.	
9,282,688	B2	3/2016	Casper et al.	
2002/0022929	A1	2/2002	Ell	
2002/0024665	A1 *	2/2002	Masten	A01M 7/0089 356/328
2008/0110026	A1	5/2008	Marcoe	
2009/0293442	A1	12/2009	Chang et al.	
2011/0022231	A1	1/2011	Walker	
2011/0046785	A1	2/2011	Zeelen	
2011/0047951	A1	3/2011	Moore	
2011/0211733	A1	9/2011	Schwarz	
2012/0096823	A1	4/2012	Moore	
2013/0204437	A1	8/2013	Koselka	
2013/0325346	A1	12/2013	McPeek	
2014/0168412	A1	6/2014	Shulman et al.	
2014/0260148	A1	9/2014	Jens	
2014/0314280	A1 *	10/2014	Lee	G06K 9/00697 382/110
2015/0027040	A1 *	1/2015	Redden	A01M 21/046 47/1.3
2016/0078304	A1	3/2016	Bremer et al.	

FOREIGN PATENT DOCUMENTS

JP	03506779	B2	3/2004
JP	2009027977	A	2/2009
SU	1045848	A1	10/1983
SU	1289412	A1	2/1987
WO	WO9625842	A1	8/1996
WO	WO9853961	A1	12/1998
WO	WO2005092077	A3	3/2006
WO	WO2007088225	A1	8/2007
WO	WO2008037035	A1	4/2008
WO	WO2006063314	A3	4/2009
WO	WO2010063075	A1	6/2010
WO	WO2011041924	A1	4/2011
WO	WO2015121809	A1	8/2015

OTHER PUBLICATIONS

Authorized Officer Arnaud Benedetti, International Search and Written Opinion for International Application No. PCT/US2016/028631, dated Jul. 13, 2016, 13 pages.

* cited by examiner

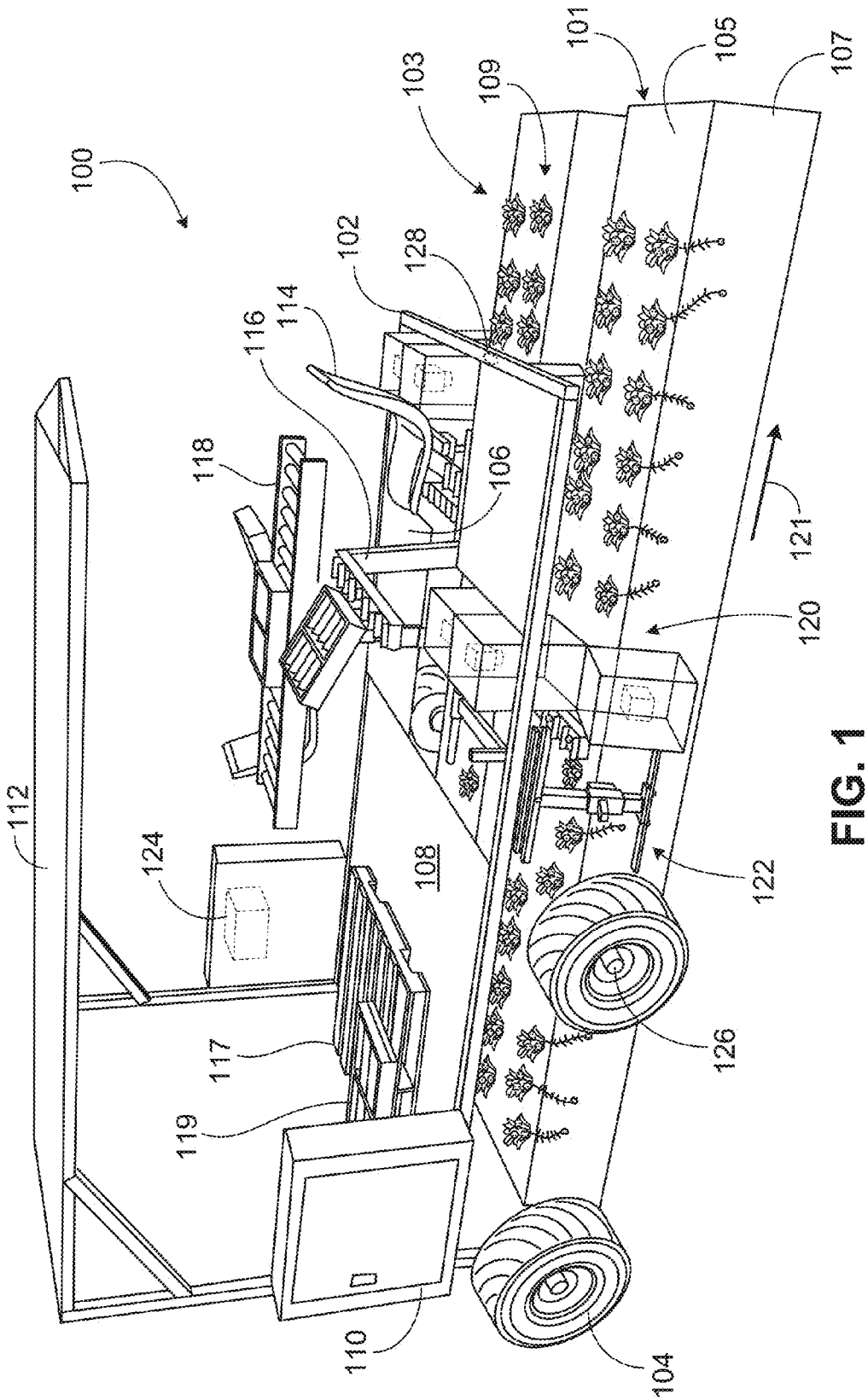

100
101
102
103
104
105
106
107
108
109
110
112
114
116
117
118
119
120
121
122
124
126
128

FIG. 1

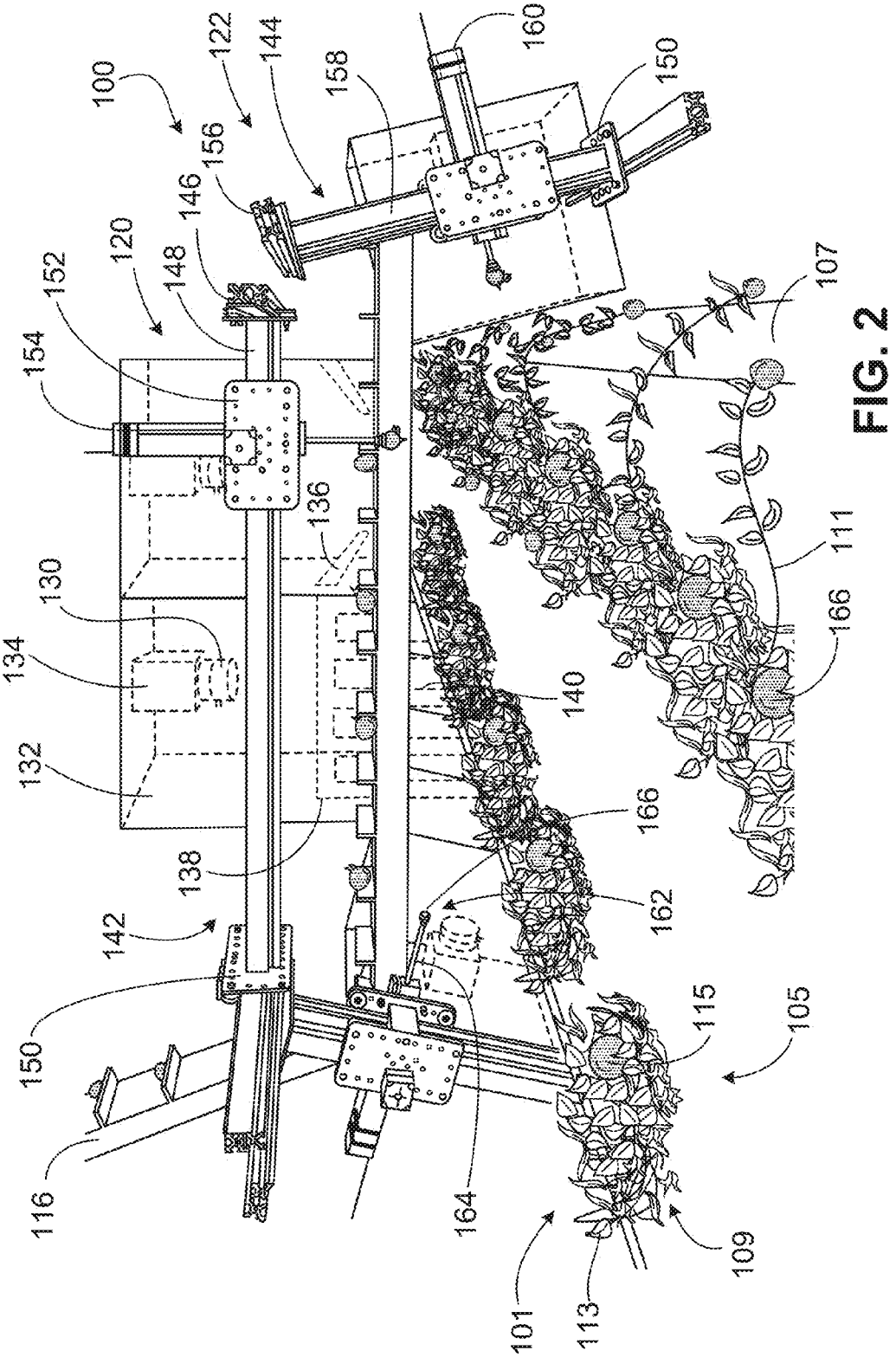

100
122
144
158
160
150
156
146
120
148
152
154
107
136
111
130
134
166
140
132
166
138
162
142
150
115
105
116
164
101
113
109

FIG. 2

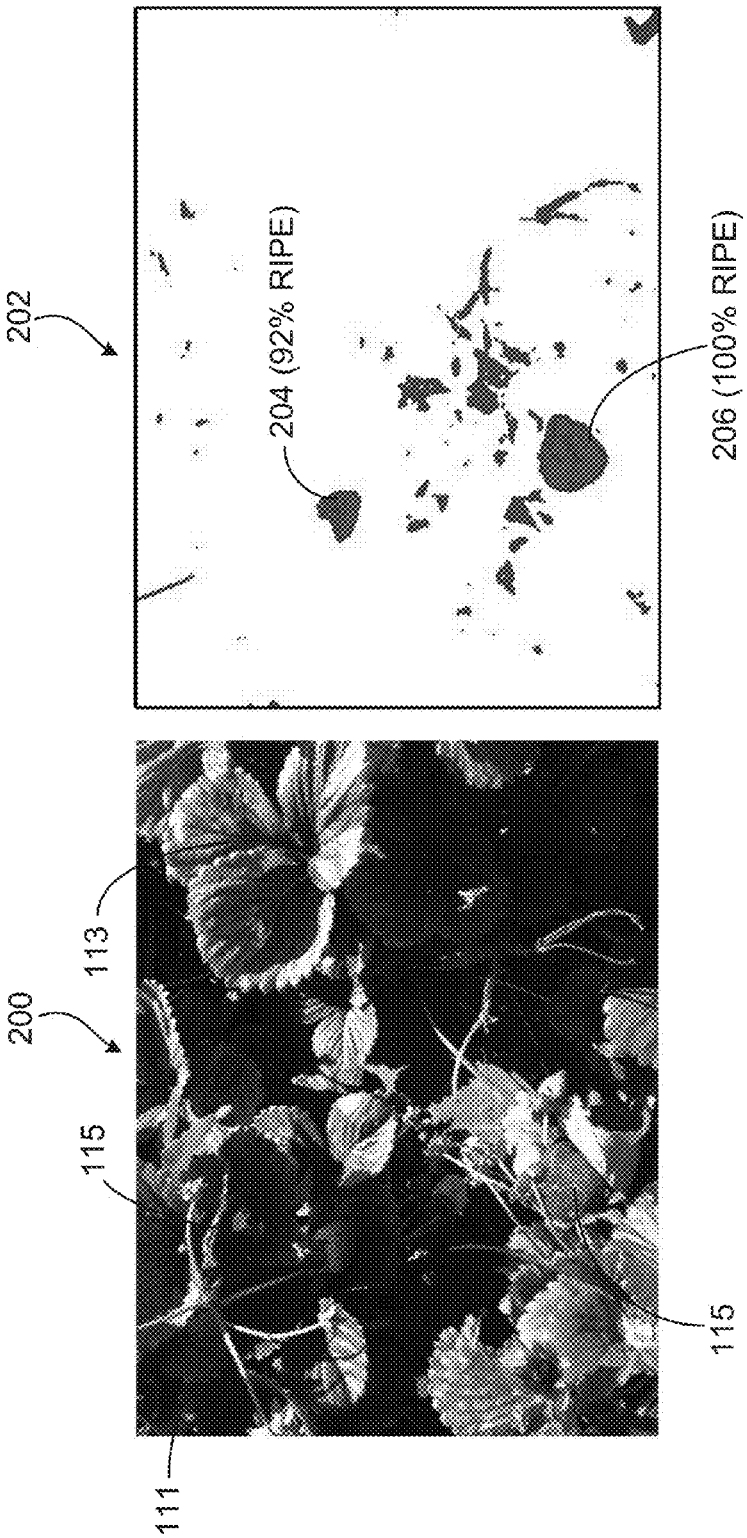


FIG. 3B

FIG. 3A

FIG. 4B

FIG. 4C

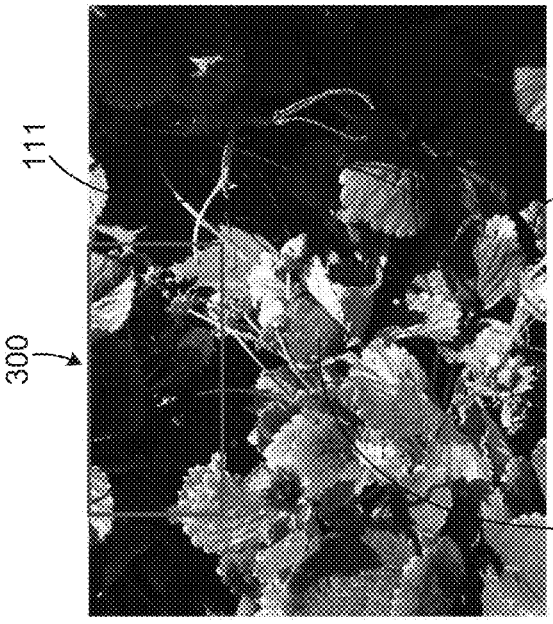


FIG. 4A

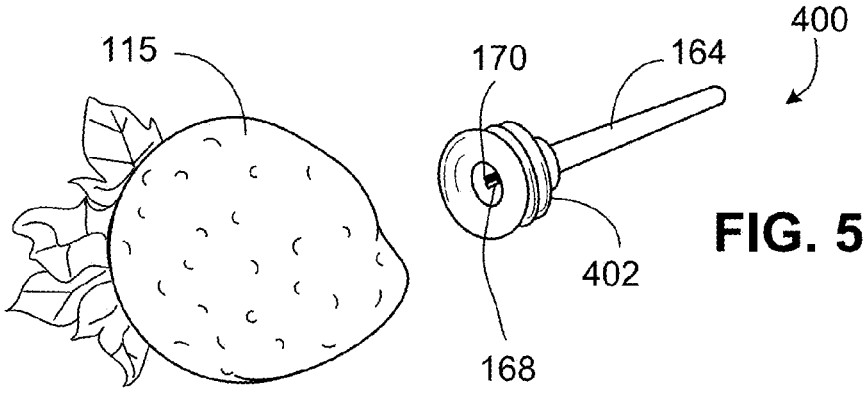


FIG. 5

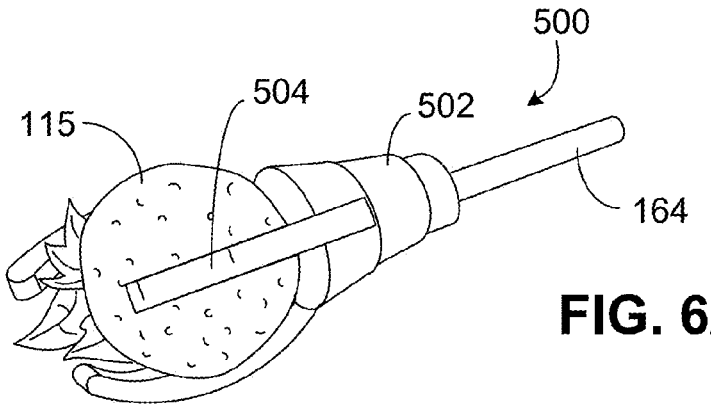


FIG. 6A

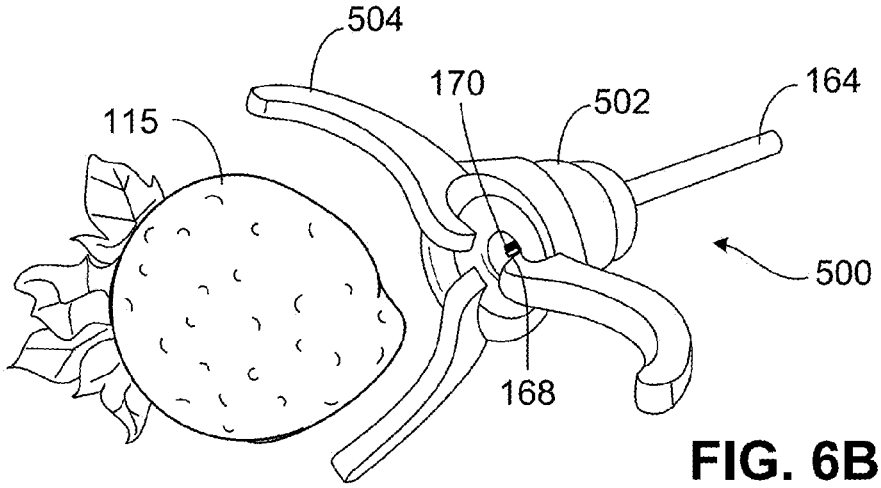


FIG. 6B

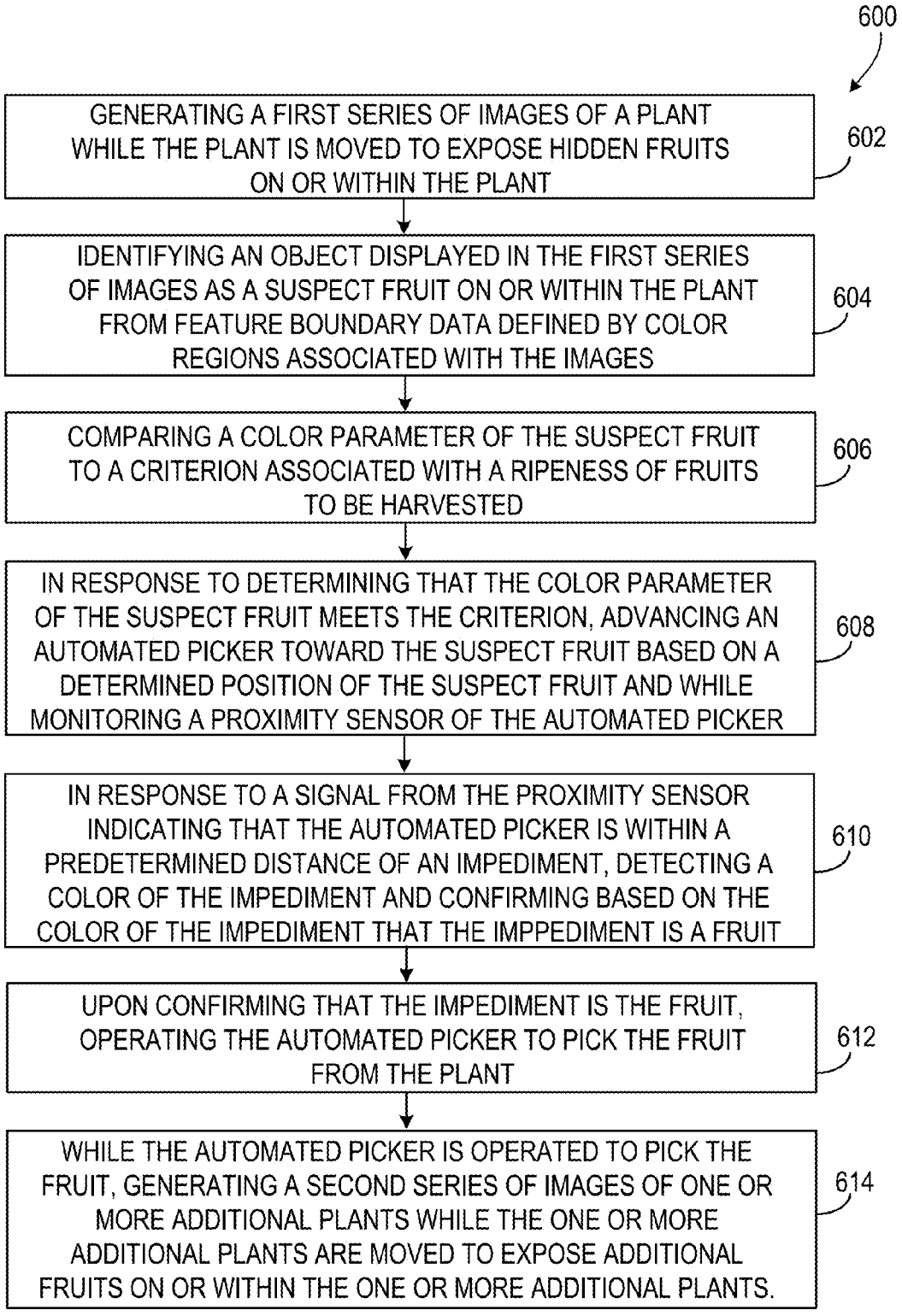

600
GENERATING A FIRST SERIES OF IMAGES OF A PLANT WHILE THE PLANT IS MOVED TO EXPOSE HIDDEN FRUITS ON OR WITHIN THE PLANT
602
IDENTIFYING AN OBJECT DISPLAYED IN THE FIRST SERIES OF IMAGES AS A SUSPECT FRUIT ON OR WITHIN THE PLANT FROM FEATURE BOUNDARY DATA DEFINED BY COLOR REGIONS ASSOCIATED WITH THE IMAGES
604
COMPARING A COLOR PARAMETER OF THE SUSPECT FRUIT TO A CRITERION ASSOCIATED WITH A RIPENESS OF FRUITS TO BE HARVESTED
606
IN RESPONSE TO DETERMINING THAT THE COLOR PARAMETER OF THE SUSPECT FRUIT MEETS THE CRITERION, ADVANCING AN AUTOMATED PICKER TOWARD THE SUSPECT FRUIT BASED ON A DETERMINED POSITION OF THE SUSPECT FRUIT AND WHILE MONITORING A PROXIMITY SENSOR OF THE AUTOMATED PICKER
608
IN RESPONSE TO A SIGNAL FROM THE PROXIMITY SENSOR INDICATING THAT THE AUTOMATED PICKER IS WITHIN A PREDETERMINED DISTANCE OF AN IMPEDIMENT, DETECTING A COLOR OF THE IMPEDIMENT AND CONFIRMING BASED ON THE COLOR OF THE IMPEDIMENT THAT THE IMPPEDIMENT IS A FRUIT
610
UPON CONFIRMING THAT THE IMPEDIMENT IS THE FRUIT, OPERATING THE AUTOMATED PICKER TO PICK THE FRUIT FROM THE PLANT
612
WHILE THE AUTOMATED PICKER IS OPERATED TO PICK THE FRUIT, GENERATING A SECOND SERIES OF IMAGES OF ONE OR MORE ADDITIONAL PLANTS WHILE THE ONE OR MORE ADDITIONAL PLANTS ARE MOVED TO EXPOSE ADDITIONAL FRUITS ON OR WITHIN THE ONE OR MORE ADDITIONAL PLANTS.
614

FIG. 7

SELECTIVELY HARVESTING FRUITS

TECHNICAL FIELD

This invention relates to selectively harvesting plant components, and more particularly to selectively removing fruits from plants in an automated manner.

BACKGROUND

Harvesting fruits involves visually examining plants from which the fruits grow and then determining which of the fruits are satisfactory for picking (e.g., removal from the plants). Criteria for determining whether a fruit is satisfactory for picking may be based on one or more parameters including a color, a size, and ripeness. Selected fruits that are deemed satisfactory for picking may be removed using a harvesting apparatus (e.g., an automated or semi-automated harvesting machine or a hand-held apparatus) or removed directly by hand. Harvesting fruits manually or using harvesting apparatuses may be limited to favorable ambient conditions (e.g., time of day and weather), require significant amounts of time, and be associated with significant costs.

SUMMARY

The invention involves a realization that improvements in selectively harvesting fruits (e.g., strawberries) in an automated manner can increase an efficiency (e.g., a productivity as it relates to a picking rate) of a harvesting operation, thereby reducing a unit cost of harvesting a fruit. Such selective harvesting of the fruits in the automated manner can further increase a duration over which the harvesting operation can occur, thereby reducing a total time required to harvest a given amount of fruits.

One aspect of the invention features a method of selectively harvesting fruits. The method includes generating a first series of images of a plant while the plant is moved to expose hidden fruits on or within the plant, identifying an object displayed in the first series of images as a suspect fruit on or within the plant from feature boundary data defined by color regions associated with the images, and comparing a color parameter of the suspect fruit to a criterion associated with a ripeness of fruits to be harvested. In response to determining that the color parameter of the suspect fruit meets the criterion, the method further includes advancing an automated picker toward the suspect fruit based on a determined position of the suspect fruit and while monitoring a proximity sensor of the automated picker. In response to a signal from the proximity sensor indicating that the automated picker is within a predetermined distance of an impediment, the method further includes detecting a color of the impediment and confirming based on the color of the impediment that the impediment is a fruit. Upon confirming that the impediment is the fruit, the method further includes operating the automated picker to pick the fruit from the plant. The method further includes generating a second series of images of one or more additional plants while the one or more additional plants are moved to expose additional fruits on or within the one or more additional plants while the automated picker is operated to pick the fruit.

Another aspect of the invention features a harvesting system that includes a machine vision system that is configured to generate a first series images of a plant while the plant is moved to expose hidden fruits on or within the plant. The harvesting system further includes a processor that is configured to identify an object displayed in the first series of images as a suspect fruit on or within the plant from feature boundary data defined by color regions associated with the images, compare a color parameter of the suspect fruit to a criterion associated with a ripeness of fruits to be harvested, and determine that the color parameter of the suspect fruit meets the criterion. The system further includes an automated picker that is operable to pick the suspect fruit from the plant, the automated picker including a proximity sensor that is configured to indicate that the automated picker is within a predetermined distance of an impediment, and a color sensor that is configured to detect a color of the impediment. The harvesting system further includes a controller that is configured to provide instructions for advancing the automated picker toward the suspect fruit based on a determined position of the suspect fruit in response to the determination that the color parameter of the suspect fruit meets the criterion, while monitoring the proximity sensor of the automated picker, and while the machine vision system generates a second series of images of one or more additional plants while the one or more additional plants are moved to expose additional fruits on or within the one or more additional plants, and confirming that the impediment is a fruit based on the color of the impediment.

In some embodiments, the first and second series of images are generated using a machine vision system including a camera that is directed toward the plant and a processor that is operable to analyze the images.

In certain embodiments, the automated picker is located rearward of the machine vision system, such that the machine vision system generates the second series of images of the one or more additional plants while the automated picker is operated to pick the fruit.

In some embodiments, the method further includes maintaining a desired distance between the machine vision system and the plant.

In certain embodiments, the method further includes adjusting Red Green Blue data of the first and second series of images to expose fruits hidden by shadows of leaves of the plant.

In some embodiments, identifying the object as a suspect fruit includes identifying the object as a strawberry.

In certain embodiments, the method further includes identifying the object as a suspect fruit using a pattern recognition algorithm.

In some embodiments, the pattern recognition algorithm includes a blob analysis.

In certain embodiments, the blob analysis identifies regions of the object that share one or more colors and determines a border around the regions that defines a pattern of the object.

In some embodiments, identifying the object as a suspect fruit includes comparing the pattern of the object to a known pattern of the fruit.

In certain embodiments, the pattern of the object includes a shape of the object.

In some embodiments, comparing the color parameter of the fruit to the criterion includes comparing a percentage ripeness of the fruit to a ripeness threshold.

In certain embodiments, the predetermined position of the suspect fruit is a two-dimensional location.

In some embodiments, the method further includes, before advancing the automated picker toward the suspect fruit, aligning the automated picker with the two-dimensional location of the suspect fruit.

In certain embodiments, the predetermined distance is a zero distance, such that the color of the impediment is detected in response to contact with the impediment.

In some embodiments, the automated picker is a suction picker.

In certain embodiments, the automated picker is a talon picker.

In some embodiments, the method further includes moving the plant by blowing air toward the plant while the first series of images is generated.

In certain embodiments, the method further includes moving the plant by brushing the plant from side to side with a flexible comb while the first series of images is generated.

In some embodiments, the machine vision system includes a hood surrounding the camera and reducing an amount of natural light incident on the plant.

In certain embodiments, the camera generates an image every 200 ms.

In some embodiments, the percentage ripeness is calculated based on colors of pixels in the images.

In certain embodiments, blowing air toward the plant includes alternately directing pulses of air toward the plant from different directions.

In some embodiments, the method further includes controlling the automated picker to deposit the fruit atop a conveyor.

Various implementations of these concepts may provide one or more advantages, particularly as to harvesting speed and/or accuracy. For example, by continuing to generate additional images of additional plants located ahead of the automated picker while the automated picker is manipulated to remove fruits and while the plants ahead of the automated picker continue to be moved, the harvesting system can achieve an advantageously high picking rate (e.g., a strawberry picking rate). Moreover, such parallel operations can offer additional time for the image processing system to develop an accurate determination of the location and ripeness of fruits to be picked. Incorporating distance and/or color sensing into the picking mechanism can further increase the accuracy of the picking process, and can enable higher mechanism speeds without damaging sensitive fruits.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages of the invention will be apparent from the description, drawings, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

FIG. **1** is a perspective view of a harvesting system.

FIG. **2** is a rear perspective view of a portion of the harvesting system of FIG. **1**.

FIGS. **3**A and **3**B respectively display a standard image acquired by a camera of the harvesting system of FIG. **1** and a machine vision view generated by a processor of the camera.

FIGS. **4**A, **4**B, and **4**C respectively display a standard image acquired by a camera of the harvesting system of FIG. **1**, an enhanced image produced by a processor of the camera, and a machine vision view generated by the processor of the camera.

FIG. **5** is a perspective view of an embodiment of a picking device of the harvesting system of FIG. **1**.

FIGS. **6**A and **6**B are perspective views of an embodiment of a picking device of the harvesting system of FIG. **1**, shown in closed and open states, respectively.

FIG. **7** is a flow chart of an example process for harvesting fruits.

Like reference symbols in the various figures indicate like elements.

DETAILED DESCRIPTION

A harvesting system for selectively removing plant components from plants is described below. The described harvesting system includes picking systems, manipulation devices, machine vision systems, and associated control elements that allow the harvesting system to remove selected plant components from their respective plants in an automated and efficient manner, thereby substantially reducing the time required to remove the selected plant components as compared to the time required to remove the selected plant components using conventional harvesters. Plant components that may be removed by the harvesting system include, for example, vegetables and fruits, such as berries (e.g., strawberries, blueberries, raspberries, and blackberries), citrus fruits, apples, pears, and peaches.

FIG. **1** displays a perspective view of a harvesting system **100** that is operable to selectively remove a variety of fruits (e.g., strawberries) from plants in an automated manner. In some examples, the harvesting system **100** may be self-propelled and steered by an operator (e.g., an operator riding atop the harvesting system **100** or a remote operator). In some examples, the harvesting system **100** may be configured to operate autonomously based on GPS mappings. In some examples, the harvesting system **100** may be configured to operate with other vehicles, such as a tractor that can pull and guide the harvesting system **100** through a field. In such cases, the harvesting system **100** may be attached to the tractor via a three-point hitch or any other suitable attachment mechanisms known to a person skilled in the art. For purposes of illustration, only the components of the system that are significant to the description of operation for berry picking and sorting are shown. However, it will be understood that other standard electrical and mechanical components will be included. For example, the system may include a generator and/or batteries for powering the electrical components.

In the example of FIG. **1**, the harvesting system **100** is positioned over two spaced beds **101** of plants **103** (e.g., strawberry plants) that are located in a field. The beds **101** are elevated with respect to a ground of the field such that each bed **101** has a top surface **105** and two opposing side surfaces **107**. As illustrated, the plants **103** are arranged in two spaced seed lines **109** along the top surface **105** of each bed **101**. The plants **103** include stems **111**, leaves **113** that line the stems **111**, and strawberries **115** that extend from tips of the stems **111** (shown in FIG. **2**). In some examples, some of the stems **111** may hang over the side surfaces **107** of the beds **101**.

In the example of FIG. **1** (e.g., where the harvesting system **100** is positioned in a field of strawberries), the beds **101** have a height of about 20 cm to about 50 cm (e.g., 38 cm), a top width (e.g., as measured along the top surfaces **105** of the beds **101**) of about 60 cm to about 90 cm (e.g., 76 cm), and a base width (e.g., as measured along the ground of the field) of about 80 cm to about 110 cm (e.g., 94 cm). In some examples, the beds **101** are spaced apart (e.g., as measured between respective centerlines of the beds **101**) by about 115 cm to about 145 cm (e.g., 132 cm). In some

examples, the seed lines **109** are spaced apart by about 30 cm to about 60 cm (e.g., 43 cm) along the beds **101**. In some examples, the plants **103** arranged along a seed line **109** are spaced part by about 20 cm to about 50 cm (e.g., 38 cm). Accordingly, the harvesting system **100** may be configured to operate on the beds **101** of plants **103**.

The harvesting system **100** includes a frame **102** supported by four wheels **104** that transport the harvesting system **100** in a direction of travel **121**, frontal platforms **106** and a rear platform **108** extending across lower portions of the frame **102**, two electrical enclosures **110** mounted to an upper portion of the frame **102**, and a cover **112** extending from the upper portion of the frame **102**. The cover **112** may support lighting devices for illuminating portions of the harvesting system **100** and portions of the surrounding field (e.g., during low light conditions). In some examples, the cover **112** may shield portions of the harvesting system **100** from sunlight and precipitation. Pallets **117** and containers **119** of strawberries **115** may be supported on the rear platform **108**. The harvesting system **100** also includes two opposite facing chairs **114** (e.g., and associated monitors, not shown) where personnel can sit to visually inspect the strawberries **115** and package the strawberries **115** in the containers **119**. The harvesting system **100** further includes a lower conveyor **116** that transports the harvested strawberries **115** upward towards the operators for placement into the containers **119** and an upper conveyor **118** that transports the containers **119** rearward for stacking on the pallets **117**. A foreman will supervise the personnel, steer the harvesting system **100**, and monitor the operation of the harvesting system **100**. Two individuals (e.g., residing on the rear platform **108**) will palletize the containers **119** and prepare empty containers **119** for the personnel inspecting and packaging.

The harvesting system **100** is configured such that the wheels **104** are located along the outer side surfaces **107** of two spaced beds **101** of plants **103**. The wheels **104** and suspension support the frame **102** (e.g., and any components mounted to the frame **102**) of the harvesting system **100** at a desired height above the raised bed **101**.

Referring to FIG. **2**, the portion of the harvesting system **100** that passes over each bed **101** includes two machine vision systems **120** that image the plants **103**, that identify the strawberries **115** within the plants **103**, and that select strawberries **115** to be removed from the plants **103**. One machine vision system **120** is located along each bed **101** of plants. The harvesting system **100** also includes manipulating devices (e.g., air nozzles **136** and a flexible comb **138** shown in FIG. **2**) for moving the plants **103** (e.g., the leaves **113** of the plants **103**), two picking systems **122** that remove selected strawberries **115** from the plants **103**, and a programmable logic controller (PLC) **124** that is located within one of the electrical enclosures **110** and electrically coupled to the machine vision systems **120**.

Referring back to FIG. **1**, the harvesting system **100** additionally includes an encoder **126** that is operable to detect an angular velocity of the wheels **104** and an ultrasonic sensor **128** that is operable to detect a distance and maintain a desired distance between the machine vision systems **120** (e.g., cameras **130** of the machine vision systems **120**) and the top surfaces **105** of the beds **101**. For example, the machine vision systems **120** and the picking systems **122** are supported by frames (e.g., frames that are adjustable via associated actuators and that are moveably attached to the frame **102**) that are adjusted automatically in vertical and lateral directions to optimize their positions relative to the beds **101**. The encoder **126** is located within a hub of one of the wheels **104**, and the ultrasonic sensor **128** is located forward of the machine vision systems **120** along the frame **102** of the harvesting system **100**. A GPS system (e.g., located within one of the electrical enclosures **110**) provides a field location to the PLC **124**.

As shown in FIG. **2**, each machine vision system **120** includes four cameras **130** (e.g., one camera **130** located above each seed line **109** and one camera **130** located along each side surface **107** of the bed **101**). The machine vision system **120** further includes four hoods **132** that respectively surround the cameras **130**. The cameras **130** are oriented and positioned to image respective fields of view along the top surface **105** and along the side surfaces **107** of the bed **101** of plants **103**. Accordingly, each camera **130** and respective hood **132** is oriented approximately perpendicular to the top surface **105** or a respective side surface **107** of the bed **101** of plants **103**. In some examples, the cameras **130** are spaced (e.g., as measured from lenses of the cameras **130**) from the top surface **105** or a respective side surface **107** of the bed **101** of plants **103** by about 30 cm to about 80 cm (e.g., 76 cm). In some examples, a distance between the lateral cameras **130** and the side surfaces **107** of the bed **101** is smaller than a distance between the upper cameras **130** and the top surface **105** of the bed **101**. The hoods **132** are adapted to block (e.g., reduce the amount of) natural light, which varies depending on a season, weather, and a time of day, that would otherwise impinge upon the plants **103** in the fields of view.

One or more LEDs are located on each side of each camera **130**. The LEDs have filters for sufficient illumination and desired image characteristics. The cameras **130** may be standard resolution, color video graphics array (VGA) cameras known to a person skilled in the art. For example, the cameras **130** may have a pixel count of 480×640 and image a 35 cm×45 cm field of view. The camera resolution (e.g., pixel dimension) of such a field of view may be 0.075 cm, which is adequate for identifying individual stems **111**, leaves **113**, and strawberries **115** of the plants **103**. The cameras **130** can acquire images every 200 ms, allowing the cameras **130** to acquire three images of a same region of a plant **103** while the harvesting system **100** moves at a predetermined speed (e.g., about 10 cm/s).

FIGS. **3**A and **3**B display an image **200** acquired by a camera **130**, and a corresponding machine vision view **202** generated by a respective processor **134** of the camera **130**, respectively. Following capture of the image **200** by the camera **130**, the processor **134** performs a blob analysis on the image **200** to generate the machine vision view **202**. That is, the processor **134** performs a mathematical analysis that finds regions in the image **200** that share the same one or more properties (e.g., the same one or more colors) and combines the regions into blobs. In particular, the regions of interest exhibit a range of red colors that meet a ripe color criterion (e.g., a ripe color threshold or ripe color range) for a strawberry **115** and a range of white colors (shown as blue in the machine vision view **202**) that meet an unripe color criterion (e.g., an unripe color threshold or an unripe color range) for a strawberry **115**. Accordingly, the processor **134** finds pixels in the image **200** that meet the ripe color criterion and pixels in the image **200** that meet the unripe color criterion.

The processor **134** then combines the pixels meeting the ripe and unripe color criteria (e.g., pixels that are adjacent or sufficiently close to each other) into a blob (e.g., as illustrated by the blobs **204**, **206**) and draws a border around the blob, thereby defining a pattern (e.g., a shape) of the blob. The processor **134** further determines a size of the blob (e.g.,

a length and/or a width of the respective pattern). The processor **134** compares the pattern and size of the blob to known (e.g., stored) patterns and sizes of strawberries. In some examples, the known patterns and sizes may be associated with shapes and sizes of entire strawberries or portions of strawberries. Blobs that have patterns that sufficiently match known patterns of strawberries and that meet a minimum size threshold (e.g., a stored threshold value) for a strawberry are identified as strawberries **115**. Blobs that have patterns that do not have recognizable features (e.g., recognizable shape profiles) or that do not meet the minimum size threshold for a strawberry are ignored by the processor **134** and left on the plant **103**.

Once a blob is identified as a strawberry **115**, the processor **134** determines a ripeness of the strawberry **115** by further analyzing the pixels that define the blob. In particular, a percentage ripeness (e.g., shown as 92% ripeness of the blob **204** and 100% ripeness of the blob **206**) is calculated as a ratio of the area of the pixels meeting the ripe color criterion to the area of all of the pixels defining the blob. The processor **134** then identifies select strawberries **115** to be harvested from the plant **103** as strawberries **115** having a ripeness that meets a ripeness threshold (e.g., typically a stored ripeness threshold value of 85%).

The processor **134** runs an algorithm to determine digital image position coordinates of each selected strawberry **115** (e.g., xy position coordinates of centroids of the respective blobs in a digital coordinate system of the digital image). The processor **134** further determines an orientation of each selected strawberry **115** (e.g., defined as an angle of a major axis of the respective blob relative to an x axis or y axis extending through the digital image position coordinates of the blob). In some examples, the orientation of a selected strawberry **115** may be determined according to an orientation of a blob (e.g., corresponding to a stem attachment region) that is adjacent to the blob associated with the selected strawberry **115**. For example, a stem attachment region (e.g., a portion of a stem **111** located at the top of a strawberry **115**) may be identified by a separate color and pattern-based blob analysis. The processor **134** then provides the digital image position coordinates, the orientations of the selected strawberries **115**, and the machine vision views to the PLC **124**. The processor **134** performs the analysis on each image (e.g., the image **200**) once the image is acquired and subsequently provides the resultant information to the PLC **124** in a continuous manner.

Using the above-described blob analysis, the harvesting system **100** can quickly process large amounts of information to recognize patterns, determine ripenesses, determine centroid locations, and determine orientations to locate fruits and determine whether the fruits are ripe enough for picking. In contrast, conventional fruit picking systems using other types of analyses (e.g., spectral analyses) may, in some examples, only determine specific wavelengths of energy corresponding to respective regions in the images. As compared to such conventional analyses, the above-described blob analysis is more accurate, provides more information, and is more successful in correctly identifying strawberries.

The PLC **124** processes the digital image position coordinates, the orientations of the selected strawberries **115**, and the machine vision views (e.g., such as the machine vision view **202**) to generate a virtual Cartesian coordinate system (e.g., an xy coordinate system) that is located relative to the lens plane of the camera **130** and that accounts for the motion of the harvesting system **100**. In a continuous manner, the PLC **124** compiles the information associated with three consecutive machine vision views (e.g., such as the machine vision view **202**) at a time and determines a position of each selected strawberry **115** in the virtual coordinate system (e.g., the position of the strawberry **115** relative to a picking device **162** of the picking system **122**, shown in FIG. **2**), a ripeness of the selected strawberry **115**, and an orientation of the selected strawberry **115**. The position, ripeness, and orientation of the strawberry **115** may be calculated as an average position, an average ripeness, and an average orientation based on respective positions, ripenesses, and orientations associated with each of the three consecutive machine vision views. The PLC **124** may then provide instructions for controlling the picking system **122** to pick the selected strawberry **115** based on the position of the selected strawberry **115** in the virtual coordinate system.

FIGS. **4A-4C** show an image **300** acquired by the camera **130**, an enhanced image **304** produced by the processor **134**, and a machine vision view **302** generated by the processor **134**, respectively. In some examples, the processor **134** varies the Red Green Blue (RGB) data of the pixels (e.g., such that the Red level is greater than twice the Green level and such that the Red level is twice the Blue level) in the image **300** prior to performing the blob analysis, in order to brighten the image **300**, to enhance the pixel colors in the image **300**, and/or to increase contrast among the colors in the image **300**, thereby producing the enhanced image **304** (displaying a portion of the image **300** provided in the rectangular outline). Such processing can improve the detection of strawberries **115** in dim light (e.g., at night or when the strawberry **115** is shadowed by leaves **113**, stems **111**, or other plant material) or in cases where the coloration of the strawberries **115** is affected by moisture or other environmental contaminants.

Referring again to FIG. **2**, the harvesting system **100** includes plant manipulation devices that may be used to move the stems **111**, leaves **113**, and other plant materials from side to side in order to expose hidden strawberries **115** to the respective camera **130**. According to an actuation rate of the manipulation devices and the image acquisition rate (e.g., 5 fps) of the camera **130**, at least one of the three images showing a particular region of the plant **103** will capture a particular strawberry **115** in an exposed state. In one example, the manipulation devices are air nozzles **136** located on opposite sides of an internal surface of the hood **132**. The air nozzles **136** can apply controlled bursts of air to the plants **103** in an alternating manner while the camera **130** acquires images of the plants **103**. Accordingly, the alternating air bursts from the nozzles **136** on either side of the seed line **109** move the stems **111**, leaves **113**, and other plant materials from side to side to expose hidden strawberries **115**.

In another example, the plant manipulation device is a flexible comb **138** that is mounted to the hood **132** at a location below the camera **130** and above the plants **103**. The comb **138** has flexible finger-like projections **140** that extend down into the plants **103** and are moved back and forth across the plants **103** while the camera **130** acquires images of the plants **103**. In this manner, the finger-like projections **140** move the stems **111**, leaves **113**, and other plant materials from side to side to expose hidden strawberries **115**. While examples of each of these plant manipulation devices are shown in FIG. **2** for purposes of illustration, it will be understood that either or both of these devices may be provided to manipulate the plants along any given seed line **109**.

Still referring to FIG. **2**, the picking system **122** includes an upper movement frame **142** located above the bed **101** of plants **103** and two lateral movement frames **144** respec-

tively spaced from the side surfaces **107** of the bed **101** of plants **103**. The upper movement frame **142** includes two opposing horizontal rails **146** oriented parallel to a length of the bed **101** and a horizontal rail **148** oriented perpendicular to the length of the bed **101**. The horizontal rail **148** extends between and is moveable along the horizontal rails **146** via opposing clamps **150**. The upper movement frame **142** further includes a clamp block **152** that is moveable along the horizontal rail **148**. The clamp block **152** carries a vertical rail **154** (e.g., oriented perpendicular to the top surface **105** of the bed **101**) that is moveably secured to the clamp block **152**. In this manner, the vertical rail **154** is moveable vertically with respect to the clamp block **152** and moveable horizontally along the horizontal rail **148**. In some embodiments, the horizontal rails **146**, **148** are positioned about 4 cm to about 12 cm (e.g., 8 cm) below the frame **102** of the harvesting system **100**.

Each lateral movement frame **144** includes two rails **156** oriented parallel to the length of the bed **101** and a rail **158** extending between the two rails **156**. The rail **158** is moveable along the rails **156** via opposing clamps **150**. Each lateral movement frame **144** further includes a clamp block **152** that is moveable along the rail **158** and a rail **160** (e.g., oriented perpendicular to the side surface **107** of the bed **101**) that is moveably secured to the clamp block **152**. In this manner, the rail **160** is moveable perpendicularly with respect to the clamp block **152** and moveable axially along the rail **158**. In some embodiments, the rails **156**, **158** are positioned with respect to the frame **102** of the harvesting system **102** such that the rails **156**, **158** are spaced about 10 cm to about 20 cm (e.g., 15 cm) from the side surfaces **107** of the beds **101** (e.g., as measured perpendicularly from the side surfaces **107** of the beds).

The picking system **122** further includes three picking devices **162** (e.g., robotic pickers) that are moveable by the upper movement frame **142** and by the lateral movement frames **144**. In particular, an upper picking device **162** extends from the vertical rail **154** of the upper movement frame **142** and two lateral picking devices **162** respectively extend from each of the rails **160** of the lateral movement frames **144**. The movement frames **142**, **144** are positioned rearward of the machine vision systems **120** (e.g., rearward relative to the direction of travel **121** of the harvesting system **100**). Accordingly, the picking devices **162** follow behind the cameras **130**. For example, in some embodiments, the picking devices **162** are positioned about 40 cm to about 80 cm (e.g., about 60 cm) rearward of the cameras **130**. Accordingly, the picking devices **162** are located outside of the fields of view of the cameras **130** and are guided to pick strawberries **115** that have been selected based on previously acquired images while the cameras **130** continue to acquire and process new images.

According to control signals provided by the PLC **124** based on images previously acquired by the respective camera **130**, the horizontal rail **148** can be moved along the horizontal rails **146** to move (e.g., translate) the upper picking device **162** along or opposed to the direction of travel **121** of the harvesting system **100**, and the respective clamp block **152** can be moved along the horizontal rail **148** to move (e.g., translate) the upper picking device **162** along a direction that is transverse to the direction of travel **121**. In this manner, the horizontal rail **148** and the clamp block **152** can be controlled to move the upper picking device **162** along the top surface **105** of the bed **101** in each of the x and y directions of the virtual coordinate system in the lens plane of the respective camera **130**. Similarly, according to control signals provided by the PLC **124** based on the images previously acquired by the camera **130**, the vertical rail **154** can be controllably moved with respect to the clamp block **152**, to move (e.g., translate) the upper picking device **162** perpendicularly with respect to the top surface **105** of the bed **101**. In this manner, the upper picking device **162** can be moved toward or away from the top surface **105** of the bed **101** in a direction (e.g., a z direction) that is perpendicular to the x and y directions of the digital coordinate system located in the lens plane of the camera **130** to pick a strawberry **115** selected based on the previously acquired images.

According to control signals provided by the PLC **124** based on images previously acquired by the respective camera **130**, the rails **158** can be moved along the rails **156** to move (e.g., translate) the lateral picking devices **162** along the side surfaces **107** of the beds **101**, and the respective clamp blocks **152** can be moved along the rails **158** to adjust a height of the lateral picking devices **162**. In this manner, the rails **158** and the clamp blocks **152** can be controlled to move the lateral picking devices **162** along the side surfaces **107** of the beds **101** in each of two orthogonal directions of the lens plane of the respective camera **130**. Similarly, according to control signals provided by the PLC **124** based on the images previously acquired by the camera **130**, the rails **160** can be controllably moved with respect to the clamp block **152** to move (e.g., translate) the lateral picking devices **162** perpendicularly with respect to the side surfaces **107** of the bed **101**. In this manner, the lateral picking devices **162** can be moved toward or away from the side surfaces **107** of the bed **101** in a direction (e.g., a z direction) that is perpendicular to the x and y directions of the digital coordinate system located in the lens plane of the camera **130** to pick a strawberry **115** selected based on the previously acquired images. In some examples, the rails **148**, **154**, **158**, **160**, and the clamp blocks **152** may be moved at speeds between about 1 cm/s and about 60 cm/s to translate the picking devices **162**.

Each of the picking devices **162** includes an extension member **164** that projects from a respective rail **158**, **160** and a grasping member **166** located at an end of the extension member **164**. Each of the picking devices **162** includes a proximity sensor (e.g., a laser sensor) and a color sensor (e.g., a laser sensor) that are located within the grasping member **166**. The proximity sensor (e.g., such as a proximity sensor **168** shown in FIGS. **5** and **6**B) is responsive to distance between the picking device **162** and an object (e.g., a strawberry **115** selected by the processor **134** of the respective camera **130**). Once a picking device **162** is positioned according to the xy position coordinates of the selected strawberry **115**, the picking device **162** is moved towards (e.g., in the z direction with respect to the virtual coordinate system) the selected strawberry **115** until the proximity sensor is within a predetermined distance of (in some cases, in contact with) an object.

The color sensor within the grasping member **166** analyzes reflected light after stimulation of an object with a laser beam to indicate the color of the object. Based on a signal from the color sensor (e.g., such as a color sensor **170** shown in FIGS. **5** and **6**B), the PLC **124** confirms whether the sensed object is of the color of the desired fruit (e.g., a red strawberry **115** as opposed to a green leaf **113**). Upon determining that the sensed object proximate the grasping member **166** is a strawberry **115**, then the picking device **162** is actuated by a servo actuator to gently grasp the selected strawberry **115** and to pull the strawberry **115** from its stem **113**. Action of the grasping member **166** is controlled to minimize damage (e.g., bruising) of the strawberry **115**.

FIG. **5** illustrates one example of the picking device, in the form of a suction picker **400** that utilizes suction (e.g., a vacuum pressure) to attach itself to a strawberry **115** and pull the strawberry **115** from its stem. The suction picker **400** includes the extension member **164**, a suction head **402** secured to the end of the extension member **164**, a proximity sensor **168** located within the suction head **402**, and a color sensor **170** located within the suction head **402**.

FIGS. **6**A and **6**B show another example of the picking device, in the form of a talon picker **500** that utilizes actuatable fingers **504** to grasp a strawberry **115** and pull the strawberry **115** from its stem. The talon picker **500** includes the extension member **164**, a grasping head **502** secured to the end of the extension member **164** and supporting the fingers **504**, the proximity sensor **168** located within the grasping head **502**, and the color sensor **170** located within the grasping head **502**. The talon picker **500** is advanced towards the strawberry **115** while the fingers **504** are in an open state, as shown in FIG. **6**B. Upon contact of the strawberry **115** with the grasping head **502**, the fingers **504** are closed to snuggly grasp the strawberry **115** without damaging the strawberry **115**, as shown in FIG. **6**A. In an alternative embodiment, a picking system may include a talon picker that has multiple fingers that, in a closed state, provide an internal diameter that is larger than a largest expected diameter of a strawberry **115**. Such a large internal diameter allows a strawberry **115** to freely rotate within the closed fingers so that when the picker is lifted, the stem **111** of the strawberry **115** is pulled towards the bottom of the closed finger configuration, providing a severance location for the strawberry **115**.

In operation, the harvesting system may be steered by an operator as it travels along the beds of plants. As the harvesting system travels in the field, communication is maintained over a network between the operator, the PLC, the wheel encoder (e.g., to indicate a distance traveled by the harvesting system), and the GPS system so that a status of the harvesting system can be monitored. Example monitored parameters include a system location, a velocity (e.g., determined according to the angular velocity of the wheels), a number of strawberries that have been harvested, a strawberry picking rate, locations from which the strawberries have been harvested, percentage ripenesses of the strawberries, and a size range of the strawberries. The operator may change the location and/or the velocity of the harvesting system by sending appropriate instructions over the network to the PLC of the harvesting system.

FIG. **7** displays a flow chart of an example process **600** for selectively harvest fruits (e.g., strawberries) planted along beds of plants using the above-described harvesting system. As the harvesting system travels along the beds, each of the cameras generates (e.g., acquires) a series of images of a particular plant while the plant itself is moved to expose hidden strawberries on or within the plant (**602**). In some examples, the camera generates images at a rate of 5 fps, allowing the camera to generate three images of a same region of the plant while the harvesting system moves at a predetermined speed (e.g., about 10 cm/s). While the camera generates the series of images, one or more manipulating devices (e.g., one or more air nozzles and/or flexible combs) are actuated to move stems and leaves of the plant from side to side to expose hidden strawberries to the cameras.

The respective processor then identifies an object displayed within the series of images as a strawberry on or within the plant from feature boundary data defined by color regions associated with the images (**604**). For example, the processor may perform a blob analysis on the images by combining pixels that are adjacent or sufficiently close to each other and meeting a ripe color (e.g., red) criterion and an unripe color (e.g., white) criterion into a blob. The processor then determines a border around the blob, thereby defining a pattern (e.g., a shape) of the blob. The processor also determines a size of the blob. The processor then compares the pattern and size of the blob to known patterns and sizes of strawberries. A blob that has a pattern that sufficiently matches a known pattern of strawberries and that meets a minimum size threshold for a strawberry is identified as a fruit (e.g., a strawberry).

The processor compares a color parameter of the strawberry to a criterion associated with a ripeness of a strawberry to be harvested (**606**). For example, a percentage ripeness may be calculated as a ratio of the area of the pixels meeting the ripe color criterion to the area of all of the pixels defining the blob.

In response to determining that the color parameter of the strawberry meets a desired criterion (e.g., from comparing the percentage ripeness to a ripeness threshold), an automated picker is advanced toward the strawberry based on a determined position of the strawberry and while monitoring a proximity sensor of the automated picker (**608**). For example, when the percentage ripeness meets or exceeds a ripeness threshold, the processor identifies the strawberry as a selected strawberry to be harvested from the plant and provides the digital position coordinates of the selected strawberry, the orientation of the selected strawberry, and three machine vision views of the images to the PLC. Additionally, the encoder provides the angular speed of the wheels to the PLC.

The PLC then combines the three machine vision views into a single machine vision view that extends along the direction of the bed to determine the xy position (e.g., average position) and orientation (e.g., average orientation) of the selected strawberry in the virtual xy coordinate system generated by the PLC. For example, accounting for the angular speed of the wheels, the PLC calculates the xy position of the selected strawberry with respect to the respective picking device and sends commands to a motion controller accordingly. The motion controller then controls servomotors that move the appropriate rails, clamps and clamp blocks of the respective movement frame to align the picking device with the xy position of the selected strawberry. The picking device is then advanced towards the selected strawberry (e.g., along the z direction).

In response to a signal from the proximity sensor indicating that the automated picker is within a predetermined distance of an impediment, the automated picker detects a color of the impediment and confirms based on the color of the impediment that the impediment is a strawberry (**610**). In some examples, the picking device detects the color of the impediment upon contact of the impediment with the picking device (e.g., at a predetermined distance of zero). Upon confirming that the impediment is the strawberry, the automated picker is operated to pick the strawberry from the plant (**612**). For example, if the picking device confirms that the proximate object is a strawberry (e.g., based on a sensed color of the object), then the picking device is actuated to grasp and pull the selected strawberry from the plant. In some examples, the picking device may grasp the selected strawberry at a particular position based on an orientation of a stem attachment region determined by the processor.

The PLC then sends commands to the motion controller to move the picking device towards the lower conveyor of the harvester and to deposit (e.g., release) the strawberry atop an open space along the lower conveyor. The lower

conveyor transports the strawberry, as well as previously deposited strawberries, upward towards the operators and the upper conveyor. The operators examine the strawberry, and if the strawberry passes the examination, then the operators place the strawberry in the container. Once an operator determines that the container is sufficiently filled with strawberries, the operator places the container on the upper conveyor for rearward transport. The upper conveyor transports the container rearwardly to an operator who deposits (e.g., stacks) the containers on the pallet supported by the rear platform of the harvesting system.

While the automated picker is operated to pick the strawberry, the camera continues to generate additional images of one or more additional plants (e.g., located ahead of the automated picker) as the one or more additional plants are moved to expose additional fruits on or within the one or more additional plants (**614**). Owing to the simultaneous actions of the cameras, the respective processors, and the respective picking devices, the harvesting system can achieve a strawberry picking rate as fast as one strawberry every 2 seconds, such that the harvesting system may harvest up to 30 strawberries per minute. In contrast, many conventional systems that harvest the strawberries only subsequent to completing image acquisition and processing achieve picking rates of up to about one berry every 5 seconds. Accordingly, the harvesting system may be used to harvest strawberries in a much faster manner than some conventional automated harvesters, while avoiding significant fruit damage.

While the harvesting system **100** of FIG. **1** is illustrated and described as operating over particular raised beds **101** of plants **103**, in harvesting other types of fruits (e.g., citrus fruits, apples, peaches, pears, or other types of berries, such as blueberries, raspberries, blackberries), the beds may be of different configurations and a harvesting system that is substantially similar in construction and function to the harvesting system **100** may be configured accordingly. Furthermore, while the harvesting system **100** is illustrated and described as operating over two spaced beds **101** of strawberry plants **103**, in other embodiments, a harvesting system that is substantially similar in construction and function to the harvesting system **100** can be configured to operate on more than two beds of strawberry plants (e.g., four or six beds of strawberry plants).

While the harvesting system **100** has been described and illustrated as including one machine vision system **120** and one picking system **122** per bed **101** of plants **103**, other examples may include a different number machine vision systems and picking devices. Furthermore, a harvesting system may include a different number of cameras **130** (e.g., per machine vision system **120**) and picking devices **162** (e.g., per picking system **122**).

While the picking system **122** of the harvesting system **100** has been described as operating via a three-axis (e.g., xyz) movement system (e.g., provided by the upper and lateral movement frames **142**, **144**) providing three degrees of freedom, in some embodiments, a picking system of a substantially similar harvesting system may operate via a movement system that provides additional degrees of freedom. For example, in some embodiments, a picking system may operate via a six-axis system that provides for both translation and rotation about each of the x, y, and z axes, thereby providing six degrees of freedom. In further embodiments, one or two additional degrees of freedom (e.g., translation and/or rotation) may be provided at a distal end of a picking device of the three-axis system or the six-axis system, thereby providing a four, five, seven, or eight-axis system that provides respective degrees of freedom.

Thus, while a number of examples have been described for illustration purposes, the foregoing description is not intended to limit the scope of the invention, which is defined by the scope of the appended claims. There are and will be other examples and modifications within the scope of the following claims.

What is claimed is:

1. A method of selectively harvesting fruits, the method comprising:

generating a first series of images of a plant while the plant is moved to expose hidden fruits on or within the plant;

identifying an object displayed in the first series of images as a suspect fruit on or within the plant from feature boundary data defined by color regions associated with the images;

comparing a color parameter of the suspect fruit to a criterion associated with a ripeness of fruits to be harvested;

in response to determining that the color parameter of the suspect fruit meets the criterion, advancing an automated picker toward the suspect fruit based on a determined position of the suspect fruit and while monitoring a proximity sensor of the automated picker;

in response to a signal from the proximity sensor indicating that the automated picker is within a predetermined distance of an impediment, detecting a color of the impediment and confirming based on the color of the impediment that the impediment is a fruit;

upon confirming that the impediment is the fruit, operating the automated picker to pick the fruit from the plant; and

while the automated picker is operated to pick the fruit, generating a second series of images of one or more additional plants while the one or more additional plants are moved to expose additional fruits on or within the one or more additional plants.

2. The method of claim **1**, wherein the first and second series of images are generated using a machine vision system comprising a camera that is directed toward the plant and a processor that is operable to analyze the images.

3. The method of claim **2**, wherein the automated picker is located rearward of the machine vision system, such that the machine vision system generates the second series of images of the one or more additional plants while the automated picker is operated to pick the fruit.

4. The method of claim **2**, further comprising maintaining a desired distance between the machine vision system and the plant.

5. The method of claim **1**, further comprising adjusting Red Green Blue data of the first and second series of images to expose fruits hidden by shadows of leaves of the plant.

6. The method of claim **1**, wherein identifying the object as a suspect fruit comprises identifying the object as a strawberry.

7. The method of claim **1**, further comprising identifying the object as a suspect fruit using a pattern recognition algorithm.

8. The method of claim **7**, wherein the pattern recognition algorithm comprises a blob analysis.

9. The method of claim **8**, wherein the blob analysis identifies regions of the object that share one or more colors and determines a border around the regions that defines a pattern of the object.

10. The method of claim 9, wherein identifying the object as a suspect fruit comprises comparing the pattern of the object to a known pattern of the fruit.

11. The method of claim 9, wherein the pattern of the object comprises a shape of the object.

12. The method of claim 1, wherein comparing the color parameter of the fruit to the criterion comprises comparing a percentage ripeness of the fruit to a ripeness threshold.

13. The method of claim 1, wherein the predetermined position of the suspect fruit is a two-dimensional location.

14. The method of claim 13, further comprising, before advancing the automated picker toward the suspect fruit, aligning the automated picker with the two-dimensional location of the suspect fruit.

15. The method of claim 1, wherein the predetermined distance is a zero distance, such that the color of the impediment is detected in response to contact with the impediment.

16. The method of claim 1, wherein the automated picker comprises a suction picker.

17. The method of claim 1, wherein the automated picker comprises a talon picker.

18. The method of claim 1, further comprising moving the plant by blowing air toward the plant while the first series of images is generated.

19. The method of claim 1, further comprising moving the plant by brushing the plant from side to side with a flexible comb while the first series of images is generated.

20. A harvesting system, comprising:

a machine vision system that is configured to generate a first series images of a plant while the plant is moved to expose hidden fruits on or within the plant;

a processor that is configured to:

identify an object displayed in the first series of images as a suspect fruit on or within the plant from feature boundary data defined by color regions associated with the images,

compare a color parameter of the suspect fruit to a criterion associated with a ripeness of fruits to be harvested, and

determine that the color parameter of the suspect fruit meets the criterion;

an automated picker that is operable to pick the suspect fruit from the plant, the automated picker comprising:

a proximity sensor that is configured to indicate that the automated picker is within a predetermined distance of an impediment, and

a color sensor that is configured to detect a color of the impediment; and

a controller that is configured to provide instructions for:

advancing the automated picker toward the suspect fruit based on a determined position of the suspect fruit in response to the determination that the color parameter of the suspect fruit meets the criterion, while monitoring the proximity sensor of the automated picker, and while the machine vision system generates a second series of images of one or more additional plants while the one or more additional plants are moved to expose additional fruits on or within the one or more additional plants, and

confirming that the impediment is a fruit based on the color of the impediment.

* * * * *